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Public Acceptance of Wastewater Sludge on Land

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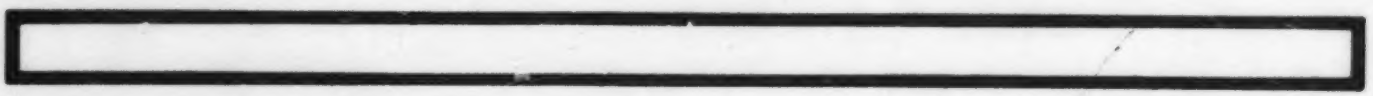

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16. ABSTRACT

The objective of this paper is to discuss the acceptance of municipal wastewater sludge on land in the United States. Application to land has been an economical disposal method for cities and a means of increasing soil productivity. Use of land for sludge disposal is increasing. Although recent research and demonstration projects have produced information needed for proper design of land application systems, the availability of the information does not always cause rural communities to accept municipal sludge. Case histories are related to show that rural-urban cooperation, technically sound planning, and educational activities help gain acceptance of landspreading.

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PUBLIC ACCEPTANCE OF WASTEWATER SLUDGE ON LAND

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Abstract

Municipal sludges have been applied to land in the United States for more than 50 years. Many municipalities have found that land application is an economical method to dispose of wastewater sludge, and farmers have used the sludge nutrients and organic matter for soil improvement. Until recently, sludge spreading projects were seldom monitored and there was little research for plausibly assessing the risk to public health or the environment. The association of landspreading with malodorous sludge farms or wastewater farms has caused some rural residents to be reluctant to accept sludge; fears of public health or environmental problems are also objections. In spite of the objections, sludge application to land for disposal has increased in popularity in the last 15 to 20 years. It is estimated that more than one-third of the municipal sludge produced is now applied to soils.

Examples of sludge spreading projects that have been accepted in rural communities and examples of others that were rejected are discussed. Sludge application demonstration and research projects that were technically sound have sometimes failed to gain public acceptance when a good educational program did not preceded the planning of the project. A demonstration of applying sludge to farm land in Ohio showed that municipal sludge effectively increased crop yields when properly applied and managed; that no environmental or health problems were reported; and that low sludge application rates diminished the adverse risks. Because this project began with a comprehensive educational program; it has been generally well accepted by the public.

Land spreading of sludge in Ohio has increased from about 55 cities in 1975 to 90 in 1980, and the sludge is being applied more responsibly and used more efficiently.

In a rural Pennsylvania community, a carefully planned and well-publicized demonstration of the proper use of municipal sludge to improve the quality of surface-mined soils also appeared to increase acceptability of the practice.

Introduction

Farmers in the United States are accepting sludge on the soil at an increasing rate. Disposal of sludge by applying it to land is, however, a relatively old practice. There are references to wastewater farming in Europe in the 16th century (Pound et al., 1973) and in the United States by the 19th century. As wastewater treatment increased and improved, more sludge was produced and some of it was applied to land. The use of sludge on land evolved from the practice of irrigating with wastewater and also from the past experience of applying other organic wastes and residues for soil improvement.

Today, different sludges are used on land in different ways--as liquid digested, air dried, or composted sludge; heat-dried waste activated sludge; or dewatered (20% to 50% solids) sludge.

Most of it is applied after having been stabilized, usually by anaerobic digestion. Cities, faced with the problem of sludge disposal, own sludge farms where anaerobically digested sludge is applied at a high rate. Esthetic problems associated with high rates of application or use of poorly stabilized sludge sometimes caused adverse public reaction (Carroll et al., 1975). Canton, Ohio, operated such a sludge farm from 1912 to 1968 (1). Liquid sludge was discharged into contour terraces on sloping grass lands. As terrace channels filled with solids, the sludge was deposited in surface waters; this led to abandonment of the system. Cities also apply liquid sludge on private farms to supply fertilizer for crops.

Dried, dewatered, or composted sludges are widely used on lawns, parks,

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(1) Miller, R. H.; T. J. Logan, D. L. Forster, and R. K. White - personal communication

golf courses, or farms as an organic fertilizer or mulch.

A survey of landspreading practices (Carrol et al., 1975) showed that the simplest and most popular method of spreading sludge on land, especially by small communities, is by hauling digested liquid sludge to privately owned farm land. A common practice is to haul sludge in a municipally owned tank truck equipped for spreading either with a pressurized spray nozzle or splash plate on the back. The truck is driven over the field, and the speed determines the rate of application. The majority of these wastewater treatment plants are activated sludge plants from 3.8 to 19.0 x 10^3 m^3/day in size. They use plant personnel to haul and spread the sludge by tank truck on a privately owned farm located within 16 kilometers of the treatment plant. Some large treatment plants also spread liquid sludge on land. Dayton, Ohio, with a 182,000 m^3/day treatment plant, has spread sludge on the same fields for more than 40 years.

Since about 1923, Milwaukee, Wisconsin, has been marketing heat-dried waste activated sludge as an organic fertilizer under the trade name of Milorganite. The name was adopted from three words Milwaukee, organic, and nitrogen (Wilson, 1973). The organic fertilizer is considered by many turf managers to be superior to mineral fertilizers for production of grass. The unit cost of nutrients in Milorganite is significantly greater than it is in mineral fertilizers, but many park managers, golf course greenskeepers, and other turf grass producers pay the high price willingly. Because the sale of Milorganite provides enough of a financial return to the city to offset part of the high cost of dewatering and drying, the cost of the system is competitive with the cost of other available disposal methods. Chicago and Houston are other large cities that have dried and successfully marketed sludge as a fertilizer. Many small communities and some large ones have followed a practice of storing air-dried sludge where homeowners can take it for fertilizing lawns and gardens. Although this is often done as a public service by the treatment plant operators and is apparently appreciated by the users of the sludge, health officials are concerned about the risk in-

volved in using undisinfected sludge on lawns and gardens. There is also concern about using sludge that contains toxic metals and organic compounds. This type of use of sludge on land will probably be more restricted by regulations in the future.

Dewatered sludge (20-50% solids) has also been applied to farmland. A typical mode of applying solid sludge is to haul it to a field in a dump truck, dump it in piles, spread it on the field, and disk it into the soil with a disk harrow. Spreading on the field may be done with a farm spreader or a commercial spreader on a truck.

Reasons for Using Sludge on Land

Farmers accept and use sludge on land for many reasons. The most obvious reason is because it is an inexpensive source of plant nutrients and organic matter when it is hauled and applied by the city. The macronutrient composition of digested sludge in the United States is shown in Table 1.

Many studies have shown that wastewater sludge applied at proper rates can supply the nitrogen and phosphorus needs of agronomic crops and produce yields equivalent to, or higher than, those produced by use of commercial fertilizer. When energy and fertilizer costs escalated during the last decade, so did interest in using municipal sludge on cropland. The cost to the farmer varies. Some are paid by the city to accept sludge; others pay a price for the sludge. The most common practice is for the municipality to furnish sludge to farmers, haul it to the farms, and spread it on their fields with no cost to the farmers.

Stabilized sludge has been shown to be significantly superior to commercial fertilizer in restoring the productivity of land disturbed by such practices as surface mining or other excavations that disturb natural surface soils. More than half of sludge nitrogen is in the organic form and becomes available gradually as mineralization occurs. The organic matter, if added in sufficient quantity, improves soil structure, moisture holding capacity, and cation adsorption capacity. Digested and composted sludges are superior to most crop residues and animal manures in improving physical characteristics

of soil because they are more stable and decompose more slowly.

A desire to conserve and recycle sludge constituents instead of throwing them away has motivated many cities to use their sludge on land. Their principal objective, however, has been to achieve simple, trouble-free, inexpensive disposal of a troublesome waste. The increasing cost of energy, the regulatory constraints placed on ocean disposal, and the scarcity of suitable landfill sites has increased interest in land application.

Constraints on Sludge Application

The 1975 survey of landspreading practices (Carroll et al., 1975) revealed that cities that practiced sludge spreading on land and the farmers that accepted the sludge considered it safe and beneficial. There was, however, almost no monitoring to verify its safety. Most of the technical literature extolled the virtues of sludge as a soil amendment, but only causually mentioned that no diseases or adverse environmental effects were observed. So, as concern for the environment and public health increased, the lack of definitive data concerning health and environmental risks deterred planners and engineers from including landspreading of sludge in plans of new or expanded wastewater treatment systems.

Although many farmers are enthusiastic about using the beneficial constituents of sludge (the plant nutrients and organic matter), others are concerned about the constituents that may be toxic to plants or cause human diseases if not properly managed. Concentrations of zinc, copper, nickel, pesticides, and industrial organic compounds could accumulate in soils and become toxic to crops. Cadmium, lead, and some organic compounds that might enter the human food chain through crops or through direct injestion by animals pose potential public health problems. Pathogenic organisms and parasitic ova found in many stabilized sludges offer some risk to public health. Although there have been many research projects conducted in recent years to define the degree of health and environmental risks involved in various systems of applying sludges to land, the data are not definitive enough to completely allay public fears.

Neighbors of the farmers receiving sludge from a distant city must also perceive the project as being beneficial, or at least not detrimental, to the community. Opposition groups form when neighbors perceive sludge use as threatening the environment, public health, land values, or future land use. A plan developed cooperatively between representatives of the rural sludge-receiving community and the city is more likely to succeed than one developed by the city before presenting it to rural people for acceptance. Failure to involve the rural community early in the planning process has resulted in rejection of plans potentially beneficial to both communities. The rural residents feel no obligation to the large city and do not want the stigma associated with being the city's dump site.

Planners and engineers are sometimes reluctant to consider land application for sludge disposal because there is no assurance that land will be available or that the guidelines and regulations will remain the same. Another deterrent may be that conventional engineering firms, accustomed to designing equipment and structures, may not appreciate the potential of the soil to assimilate wastes nor the management required to properly operate biological systems.

Status

In 1976, Bastian estimated that 25% of the municipal sludge was applied to land (Table 2); in 1979, Walker estimated 31% (Table 3). A 1981 survey of 1,011 selected publicaly owned treatment works indicated that the percentage of municipal sludge applied to land has increased to an estimated 41%. Eighteen percent of sludge applied to land was distributed as dried or composted sludge, 12% was used to produce crops that became part of the human food chain, and 12% was used on land producing non-food-chain crops.

Municipal sludge production increased from an estimated 4.5 million tonnes in 1976 to more than 8 million tonnes in 1981 because the amount of treated wastewater increased and the quality of wastewater treatment improved. Although this surprising increase may be partially accounted for by

inaccuracies and differences in procedures used in the surveys, the trend toward increased use of sludge on agricultural land is, nevertheless, unmistakable.

Although the total amount of sludge applied to land is increasing, well-planned projects are sometimes rejected. Acceptance of a land application project depends upon the community's perceiving the benefits to be greater than burdens of odor, noise, and traffic (Deese et al., 1982). The following examples of acceptance and rejection may suggest reasons for success or failure.

The Chicago Experience

The Metropolitan Sanitary District of Greater Chicago (MSDGC) hired an engineering firm in 1967 to study the feasibility of and develop a plan for applying sludge to land in central Illinois. The plan identified four prospective sites in North Central Illinois. The reasons the prospective receiving communities rejected the use of these sites included the usual fears--nuisance, and undesirable land use changes. The facts that the communities were far enough from Chicago not to be part of the sludge disposal problem and that they were not included in the planning may have contributed to their reluctance to be involved in the project. The MSDGC developed a research and demonstration project with U.S. Environmental Protection Agency (EPA) funding support to determine proper management and demonstrate the value of sludge in improvement of land. Many small demonstrations were conducted around Chicago in addition to the comprehensive study conducted by the University of Illinois.

This study of environmental changes resulting from using wastewater sludge on cropland, which began in 1967, has contributed greatly to the technology of applying sludge to land (Hinesly et al., 1977). Findings indicate that sludge applied at a rate sufficient to supply nitrogen for crops has a minimal adverse impact on the environment. Corn yields were increased effectively, and the increase in trace elements in crops was moderate (Table 4). No toxicity to plants was seen. Feeding sludge-fertilized corn to swine increased the cadmium concentration in the liver and kidneys.

The swine remained healthy and showed no signs of being adversely affected by the sludge produced grain (Hansen et al., 1979). The research data that were produced probably helped to gain approval of regulatory agencies, but they apparently did little to gain public acceptance for land application of Chicago sludge.

Fulton County, Illinois, with a large strip-mined area to be improved, approached MSDGC about using sludge to increase the productivity of the land. Although the sludge had to be transported a distance of almost 320 kilometers by barge and piped another 17 kilometers to the reclamation site, more than 2,000 hectares were purchased. Construction of sludge storage basins, pipeline, and other facilities needed to transport, store, and apply sludge began in January 1971. Additional purchases of land brought the size of the total area to more than 6,000 hectares. In addition to starting the project with the support of local government, other measures were taken to gain local support including establishment of a steering committee that included respresentatives of county and state government, local cities and towns, federal agricultural agencies, and a citizen's opposition group. A public relations firm was hired to inform the public and improve relations between the public and the project. Several other actions were taken to make the project acceptable. Lakes were opened to fishing and camping facilities were established. Both were operated by the county. Land not being reclaimed was leased to farmers for growing crops and grazing livestock. Many thousands of visitors toured the site and were told of the objectives. Despite these efforts to gain public acceptance, a citizens group of residents living near the site brought suit to halt the project and collect damages for nuisance odors created. In the beginning, sludge was pumped from the storage basins and spread on the land by spraying. When complaints of odors were made, the method of spreading was changed to inject sludge into the soil. The suit was recently resolved, and the reclamation of mined land with sludge is continuing. Although great effort was made in Fulton County to gain public approval, several aspects of the project made this difficult. Chicago was a large city disposing of its waste in a rural

community a great distance from the city. The rate of application was greater for reclaiming land than that recommended for cropland. The sludge contained higher concentrations of several trace elements than that considered desirable for sludge used in cropland. Some people were afraid that crops produced for use in the human food chain would be higher in Cd than is desirable.

The Pennsylvania Experience

In contrast to the difficulty experienced by the MSDGC, a survey of sludge disposal practices in Pennsylvania in 1967 showed that many municipal wastewater treatment plants of small and medium size were using land application as their mode of disposing of sludge. Not only were some of the sludge recipients well satisfied with the results, they complained because they could not get more sludge (Evans, 1969). Many of the wastewater treatment plants that were applying sludge to land successfully in 1967 are still doing so under state permits.

Not all cities in Pennsylvania enjoyed as much success as those visited by Evans. In 1973, EPA in an effort to help Philadelphia find a suitable alternative to ocean disposal, developed a plan to apply digested sludge to federal land holdings. Research personnel from the EPA and the U.S. Department of Agriculture evaluated several potential sites. A 260 hectare tract within the federal land area was selected, and a preliminary plan was developed to ship sludge by rail, store it in a reservoir, and spread it on land. Although the demonstration areas was chosen to be separated from the community residents by other federal land, a newspaper story concerning the plan caused public suspicion and resistance to develop. When the EPA finally tried to involve the public in the project, opposition was strong. Expressed reasons included concerns about odors, diseases, and groundwater pollution (Deese et al., 1981). A large urban community sending its sludge 240 kilometers away to a small rural community and the lack of involving rural residents in the plan's development were factors that apparently caused rejection of the project. The plans were not implemented.

After several other unsuccessful efforts to apply sludge to land, a

project of reclaiming strip-mined land with composted sludge was started and is currently proceeding successfully. In 1977, the State of Pennsylvania, with support from an EPA grant, began a research and demonstration project to reclaim three acidic surface-mined areas with wastewater sludge. Various rates of both dewatered and liquid sludges were used on 4-hectare plots in three separate locations. An intensive public information program of field days, seminars, movies, slide presentations and newspaper articles accompanied the study and gained recognition for and acceptance of the project. In 1978, Philadelphia began a similar demonstration in Western Pennsylvania. A 4-hectare site was graded, limed, treated with about 816,000 kilograms of composted sludge, and seeded with a grass/legume mixture. Monitoring the EPA project and the Philadelphia demonstration indicated no environmental or public health problems, and the lush growth of vegetation attested to the value of the sludge as a fertilizer and soil conditioner. Following the pattern of informing the public that was used in the small demonstration, the contractor expanded the area to be reclaimed. In 1979, a state permit was granted for applying Philadelphia composted sludge to 320 hectares of which 120 hectares were reclaimed. In 1980, another 280 hectares were reclaimed. In 1981, about 440 hectares were scheduled for reclamation (Bastian, 1982).

The Ohio Experience

Experience at Chicago, Philadelphia, and many other places has shown that preparation of a technically sound plan of sludge application does not always ensure public acceptance. Even publicity of the plans may not gain acceptance unless the supporters and participants include agricultural organizations and agencies that farmers know and trust. The Ohio demonstration, which began in 1976 with support of the EPA, has been successful. It emphasizes local involvement, a sound plan developed by agricultural scientists, cooperation of the rural and urban people affected, and a great amount of educational effort.

The first grant from EPA was to determine the effects of information programs on public attitudes of farmers, nonfarm rural residents, and urban

residents that were to be involved in the demonstration. The Ohio Farm Bureau Federation, which is conducting the study, enlisted the help of Ohio State University's College of Agriculture and the Ohio Environmental Protection Agency. From this experience grew the plans to study the feasibility of applying municipal sludge to agricultural land through cooperative agreements between individual farmers and the city. Knowing the history of public resistance to sludge spreading projects because of misinformation and lack of cooperation between urban and rural communities, the agricultural group started a study of ways to improve cooperation.

To determine attitudes toward sludge spreading of the various communities (farm, rural nonfarm, and urban), 600 people in each of eight selected counties received a questionnaire developed to determine (1) attitudes regarding land application, (2) current level of knowledge regarding the subject, and (3) interest in knowing more about the subject. After completing the survey, study groups from these counties attended an educational meeting conducted by the College of Agriculture at which the nature of sludge, the advantages and disadvantages of its use, and risks of adverse effects on health and environment were discussed. The same questionnaire was again answered to determine the effectiveness of the educational meetings. A few of the most pertinent conclusions are:

1. People who have had experience with sludge use on land are more willing to accept it on their farms or in their communities than those with no experience or with no knowledge about sludge use.
2. People who live on farms consider application of sludge to land to be primarily for the purpose of aiding cities to dispose of sludge. City dwellers consider sludge use as primarily to furnish fertilizer and organic matter to farmers.
3. The educational program significantly changed attitudes of both the rural and urban participants.

Who is carrying out a project is often more important than what is done, or how, in determining its acceptability. The confidence that the farmers

have in the sponsoring organization is important in gaining acceptance of and participation in such projects. The Farm Bureau is one of the oldest and largest farmer organizations in America.

In 1977, before completion of the attitudinal survey, the Ohio Farm Bureau Federation began a field demonstration. Their grant application was submitted at a time that the EPA was searching for a model demonstration of a successful way to plan, implement, and conduct a sludge use program on farm land. Such a demonstration would involve resolution of legal and institutional obstacles, follow the best available site management, and employ educational programs to publicize the project. The scope of the project was significantly expanded by adding an epidemiological study to assess the effects on the health of animals and humans from careful use of sludge on farms.

An important aspect of the project--one that distinguishes it from previous efforts to apply urban wastes on rural land--is the great number of participating agencies, organizations, and individuals that have cooperated in planning and implementing it. They represent the rural and urban communities and local, state, and federal governments. Much of the research is being done through Ohio State University.

Sludge application and site management are responsibilities of the Ohio State University's Department of Agronomy. After a soil test indicates those soils needing liming, sludge is being applied to supply the phosphorus needs of the crop as indicated by the soil test. Therefore, the application rates, which range from 0.4 to 2 tonnes of sludge solids per hectare, are lower than they would be if they were determined by the crop's nitrogen requirements. These low application rates ensure that the risk of environmental or health problems will be very low. Supplementary nitrogen and potassium are usually needed. The Department of Agricultural Engineering advises in matters concerning sludge handling and application and studies the effect of sludge on soil density and compaction.

The Department of Medical Microbiology analyzes sludge for pathogenic bacteria and viruses and evaluates sludge-treated soil to determine the rate

of survival of these pathogens. They also examine the cooperating farm families to determine any evidence of bacterial or viral infections from sludge application. The Department of Preventive Medicine cooperates in design of the epidemiological study and in analyzing the data. The epidemiological study is an important aspect of the study because it provides assurance to participants that an adverse effect on their health, if it does occur, will be treated. The health studies began in 1978; to date, no differences in rate of illness between sludge and nonsludge users have been reported. No adverse effects on farm animals have been reported. The College of Veterinary Medicine cooperates in the study on the effect of sludge use on human health and monitors the effect of sludge on the health of domestic animals.

The Cooperative Extension Service is the leader in information dissemination and in obtaining farmer cooperators. They also set up field days and collect soil and plant samples. Volunteers who receive and use the sludge and their neighbors have been fully informed of benefits and risks involved in sludge use on farms. Thus, enlightened decisions are made possible by publicity and educational programs. By involving affected residents in both the rural and urban communities, the volatile reaction that sometimes accompanies the initiation of waste disposal projects has been avoided.

Tour and field days are very important for publicizing the project. In 1978, Ohio State University established plots on the demonstration site of the University's Farm Science Review, and annual 3-day exposition of the latest methods and materials used in agriculture. About 100,000 people attended the exposition. Several thousand viewed the plots where sludge had been applied at several rates and heard the investigators discuss the benefits and risks of sludge used. Table 5 shows that corn (Zea mays L.) yields from optimally fertilized plots were not significantly different from those from sludge-treated plots.

Sludge and commercial fertilizer have been equally effective in enhancing crop growth and yields. The value of the nutrients in 1 tonne of sludge

varies from about $7.00 to $46.00 depending upon the composition of the sludge. An average sludge applied to a crop that uses the nutrients efficently, at a rate of 1.2 tonnes per hectare, is worth about $165.00 per hectare.

Although results of the project are preliminary, they indicate small risks to the environment or public health. It is apparent that publicity, educational programs, and cooperative planning can do much to alleviate the suspicion and fear that often accompany the disposal of urban wastes in a rural community.

The number of municipal wastewater treatment plants in Ohio using land application has increased from about 55 in 1975 to 90 in 1980. In addition to the increasing number of projects, public acceptance has also improved. There are several reasons for the gain in acceptance. The EPA-supported demonstrations and the involvement of the Farm Bureau as well as the approval of the state have been very helpful. A very active group of agricultural scientists from The Ohio State University have given expert guidance and conducted excellent educational programs. Improvement in the technology of land application has avoided environmental or public health problems. Most sludge is now analyzed so that farmers know what they are applying. Analysis of soils and crops is a common practice. Sludge is now applied at a rate low enough to minimize the need for monitoring (8.5 t/ha, median) (1).

Summary

Many research and demonstration projects have shown that well stabilized municipal wastewater sludge is an effective fertilizer and soil conditioner. The technology of sludge application is well enough developed to permit its use on land with a minimum of risk to the environment or public health. Even though sludge use on agricultural land has been very advantageous to both farmers and to cities when properly managed, the practice of applying a city's sludge to farm land is often rejected by rural communities. Being well informed about municipal sludge and its use decreases resistance to its use. An effective way to gain acceptance of rural people is to involve

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(1) Miller, R. H., T. J. Logan, D. L. Forster and R. K. White, personal communication

them in the planning and operation of the project. Technical assistance and guidance for agriculturalists, to be most effective, should come from the agencies and organizations that have traditionally furnished advice and counsel in matters of agricultural technology. People who live where sludge will be spread are less trusting of municipalities than they are of agricultural agencies and organizations. Giving more responsibility to agricultural agencies and organizations for distribution of sludge on land would increase acceptability of sludge use in rural communities.

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Table 1. Nutrients in Anaerobically Digested Sludge[a]

	% of Dry Solids		
	Range	Median	Mean
Total Nitrogen	0.5-17.6	4.2	5.0
Total Phosphorus	0.5-14.3	3.0	3.3
Total Potassium	0.02-2.64	0.30	0.40

[a]Adapted from Sommers (1977)

Table 2. Estimated Breakdown of Municipal Sludge Disposal[a]

Method	Municipal Sludge Disposal, %
Ocean	15
Incineration/Landfill	35
Landfill	25
Land Application	25

[a]Adapted from Bastian (1976)

Table 3. Estimated Disposition of Sludge[a]

Method of Disposition	Percentage Disposition
Ocean disposal	12
Lagoons	6
Land application Giveaway/Sale	31
Landfill Incinerator ash Stabilized sludge	 22 29

[a]Adapted from Walker (1979)

Table 4. Corn (Zea mays L.) Yields from Plots Treated with Digested Sludge[a]

	Sludge Application Rate Dry Solids t/Ha	Grain Yield t/Ha	Zn in Grain PPM	Cd in Grain PPM
1968	0[b]	4.16		
	12.8	6.03		
1969	0	8.96		
	12.1	9.34		
1970	0	5.53	32	0.30
	13.1	7.48	40	0.60
1971	0	5.06	24	0.14
	32.1	6.50	37	0.70
1972	0	8.94	22	0.14
	6.2	8.62	29	0.45
1973	0	4.00	29	0.08
	15.4	6.05	37	0.15
1974	0	3.41	28	0.09
	12.2	3.27	37	0.18
1975	0	8.15		
	8.1	9.36		

(a)Adapted from Hinesly, et al., 1977
(b)Fertilized control plots

Table 5. Corn Yields Obtained with Digested Sludge on Cropland at Columbus, Ohio

Treatment	Yields Kg/ha
	1980
Check	7,100
Fertilizer	10,497
6.72 tonnes sludge/hectar	9,129
13.44 tonnes sludge/hectar	10,727